FUNCTIONS OF A PLANNING DEPARTMENT AS APPLIED TO AN INSTRUMENT FACTORY.

Paper presented to the Institution, London Section, by B. Haviland, M.I.P.E.

PROGRESSIVE employees engaged on repetition or mass production business have long realised that efficient results can only be achieved by some form of planning, and my duty to-night is to try to give you a few illustrations, as applied to an instrument factory.

To many of you, no doubt, this address may be very elementary, but as it is, I believe it will be of interest and value to some of you.

I think we can all agree that in every case, the product one has to produce determines the magnitude of the planning, and as this subject is so vast and varied, I will confine my remarks mainly, as above stated, to an instrument factory. A " planning department " in its true sense, as a separate unit in the organisation, is not desirable. By this I mean a department specialising on planning and employing specialists. Planning as we know it is the work of a team whose endeavour is to " think before and not after," and controlled in detail by the estimating department.

Now we begin by asking who determines the product to be manufactured. This is done at conferences held at least once a month with the managing director in the chair, assisted by representatives of the sales, engineers, and factory. A definite line of action and quantity to be made by a determined date are agreed upon, and the instrument thus begun as an idea, is moulded into form on paper by the engineer and drawing office.

As to the general layout of the drawing office, the design section is on the left, the tool design section on the right, the material control and routine section in the middle, and the tracers in the front. There are many advantages of grouping these sections in one office, under one supervisor, the chief draughtsman, and it will be appreciated by some, no doubt, what these advantages are without further explanation. Each draughtsman wears a white coat (I wear one myself). It is our standard custom to do so, and each girl wears a green overall. This denotes cleanliness, a feature most essential in any organisation producing articles of a delicate and accurate quality.

The works manager then follows up with a conference attended by his team representing the engineer, drawing office, planning,

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machine shop, inspection, and assembly. The instrument, or whatever is to be manufactured, so far roughly laid out on paper, is scrutinised in every detail from all angles, and improvements in design, manufacturing costs and ease of production are all considered. The suggestions come forth with that good team spirit one desires in every business, the engineer responsible taking a delight to receive the works' point of view.

Having perfected the product so far, samples are made up in the experimental department, and after examination at a further conference, should all be well, the samples are then put on test. This is done either in the laboratory or under actual working conditions, and when finally accepted as satisfactory, manufacture can proceed.

Up to now we have dealt with the creation of a product ; now we will deal with the control of manufacturing its components. In dealing with the products of a factory when working top pressure, turning out over a million components per week, one can realise that without some intelligent pre-planning organisation, efficient results could not be achieved. Production control therefore may be divided generally into two classes :

(1) Planning in advance every successive operation to the date required on each machine, thence to the finished store.
(2) The common " follow-up " method of the slowest moving component by the production clerk, commonly known as the chaser.

As there is much variance of opinion in respect of the merits of both systems, it may be well to examine them before proceeding. From experience gained over a number of years, we have found *pre-planning* to be the more successful. It provides :

(1) A complete history of the movements of the component, recording the time in each department ; automatic transport from department to department ; cost reduction.
(2) A picture of the load on the factory, and advanced information to arrange double shift, or help outside, if required.
(3) A more accurate control of bought-out material, by regulating the flow to marry up with the dates required.
(4) A better atmosphere is created amongst the foremen, who, by working to dates, have confidence in the result.

The " follow-up " method whilst being quite common in industry requires much more effort and costs more, the latter being an item which in itself is very distressing these days, and as far as we are concerned we have dropped this method.

Having received from the sales department their order for manufacturing the product, the production office originates an instruction, known as the time table for new products (Fig. 1). The idea of this instruction is to notify all concerned that something new is on order,

and that its manufacture requires organising, and that delivery is to be made by a certain date. If you will kindly refer to the copy in your possession, you will notice the various principal stages of

Code No. X. 25182.
Qty 1st Order 1,000.

TIME TABLE FOR NEW PRODUCTS

Description of Order B.S.A. Gear Box 8/12 Ratio. Date 1.2.33.

Order of Progress	Date req'd	Date comp'd	Remarks
1 Drawings	4.2.33.		
2 Assembly & Material Lists	5.2.33.		Special Body. (Moulding already ordered).
3 Shop Orders	6.2.33.		
4 Material Orders	6.2.33.		
5 Operation List	8.2.33.		
6 Tool Design	10.2.33.		
7 Material for Assembly	10.2.33.		
8 Promise Delivery Date	17.3.33.		500 March 500 April

Expectation of failure to work to dates allocated is to be forwarded to the Works Manager ---------- Works Manager

Fig. 1.

progress, which I will explain in a few moments. The drawings in every detail ready for issue to the works, are promised by the chief draughtsman, and similarly other dates are fixed. Thus a task is set for each department, although it does not necessarily follow that each department waits for the other. All concerned co-operate and working as a team, the work is usually completed by the dates promised.

Having completed the drawings, we next come to the assembly list which covers all components for any one product, known by one code, and on this list all odd material, even the packing box, is called for. It is interesting to note that we have approximately five thousand *live* assembly lists in use at the present time, covering the whole range of our production.

The assembly list is taken by the production clerk, who prepares a "master card" for each component (Fig. 2).

This tells what product that component is used upon, the quantity required on that product and the month when wanted. The stores stock and balance of existing orders is taken into account, the net result being the quantity required to order for the new product. This record is also very useful for general reference purposes.

Technical staff now take the "master card" and also the material list, which provide all information for them to complete the "material covering and works order." Care has to be taken in

S.P.315 DESCRIPTION Driving Gear 8 teeth PRODUCT B.S.A. Gear Box YEAR CODE P.25197

Assembled Code	No. of	Aug.	Sept.	Oct.	Nov.	Dec.	Jany.	Feby.	Mar.	Apr.	May	June	July	Indents
X25224	1								500	-	500			
X25192	1								500	500				
									1000	500	500			
Stock									1025					
On Assm.									-					
/S on order									1000					
TOTALS														

Fig. 2.

planning the dates, but from experience and by reference to the load on the factory, a fairly accurate period of time can be ascertained in which the component can be manufactured. The factory load reference, I will mention in a moment.

The layout of operation for manufacture is not included and is not a part of the component drawing. This is a special record, and like all other records, and even the bulk of our drawings, we adopt the 8-in. × 5-in. standard size. This operation list takes care of all operations, departments, machines, tools, and gauges. It is a blue

1 of 1 ESTIMATE Code P.25197.

Part Driving gear.

Apparatus Gear Drive. 46-SP

OPERATIONS	Awards %	Awards Each	Nett Labour Each	MATERIALS	Material Each
Turn, form & centre (Gridley)				Description .260"of.656"dia. S.14.B. Steel rod.	
Remove pip & centre.					
Worm end.					
Cut teeth					
Remove burrs from teeth.					
Drill.				Weight .255 lbs. at	
Burr hole.					
Harden.				Recovery at	
Sandblast teeth.					
Grind stem.					
Grind end face.					
				Waste %	
Plus % Waste					
Total Labour Each				Total Material Each	

Fig. 3.

print, and is kept in order by the factory drawing section which is a part of the tool stores. It is issued out on check in the same way as a drawing or tool.

The estimate card (Fig. 3) is based upon the operation list and by reference to the card you have, the details are self-explanatory. At the back of this card, records of all orders are kept. A buff colour is

PROGRESS RECORD. CODE P.25197

DESCRIPTION Driving Gear (8 teeth) USED ON Gear Drive

S/O	QTY.	DATE RECD 1933	Operations REQTS.	1 AUTO	4 CAPS	PRESS	2 S.M.G.	5.6 DR.	3 MILLS	7 S.H.	9.10 GRD.	8 '8	Sand Blast STORE
24413	1,000	16th Feb.	200 per week commence 10th April	8th Mar.	22nd Mar.		13th Mar.	24th Mar.	16th Mar.	29th Mar.	5th Apr.	1st Apr.	10th Apr.

S.P. 537.

Fig. 4.

used for the component and a pink colour is used for the assembly. T

Again we use the operation list, and you will notice on the progress record card (Fig. 4) you have, the planning of dates and department,

DEPT. Auto. PRODUCTION RECORD CODE P.25197.
M/C. No. 33. Gridley. DESCRIPTION. S/O 24413.
Driving Gear. 8 Teeth QNTY. 1,000.
DELIVERY) Gear Drives.
REQTS.) PER WEEK - 1ST. DELIV. BY - COMPLETE BY 17th Mar
Raw Mat: Store

RECD. FROM 8th March			DELIV TO Small Machines.				MAT. DUE
DATE	QTY.	TOTAL	DATE	QTY.	SCRAP	TOTAL	REASON FOR DELAYS.
			March				
			9th	116		116	
			10th	168		284	
			11th	50		334	
			13th	129		463	
			14th	164		627	
			15th	189		816	
			16th	123		939	
			17th	87		1026	

Fig. 5.

from the first to the last operation, of the component. This card is kept in the planning section and is brought up-to-date as each operation is completed. By reference to this record, therefore, we have the position of the component in process of manufacture.

The departmental production record (Fig. 5) is part of the foreman's instruction, kept by him in a special card index box divided into days of the month, so that each card along with the works order and copy of the material requisition, is filed in the division representing the day when that order is to be started. You will thus appreciate that the foreman has an automatic control of his orders, and by easy reference he can plan his work ahead. Should there be any cause for a delay, it is the practice of the foreman to report this to his chief, so that special action can be taken to recover any time lost, if necessary.

MACHINE HOUR RECORD

KEY 510

M C NO 33
TYPE 7/8" GRIDLEY
SETTER

CODE	S/O	QUAN.	DATE REQD. 1936	M/C HRS.	MONTH	1st	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
P4394	21343	12000	12/1	120	JAN	S	/	/	/	/	/	/	S	/	/	/	/	/	/	S	/	/	/	/	/	/	S	/	/	/	/	/				
P9604	21643	2000	9/2	45	JAN																											/	/	S	/	/
"	"	"	"	"	FEB	/	/	/	/	S																										
P12096	22525	2500	16/2	40	FEB						/	/	/	/	/	/	S	/																		
P12051	23671	1000	27/2	34	FEB													/	/	/	/	/	/	S	/	/										
P18794	23952	4500	6/3	76	FEB																					/	/	/	/	/	S	/	/			
"	"	"	"	"	MAR	/	/	/	/	S	/	/	/																							
P25197	24413	1000	10/4	48½	MAR								/	/	/	/	S	/	/	/	/	/														
P6857	23543	10000	3/4	190	MAR																	/	/	S	/	/	/	/	/	/	S	/	/	/	/	/
"	"	"	"	"	APL	/	S	/	/	/	/	/	/	S	/	/	/	/	/	/	S	/	/	/	/	/										

Fig. 6.

By reference to the machine hour record card (Fig. 6) you will observe a simple method as to how we control the load of the machine, as hinted at a little earlier on. This scheme is satisfactorily working in the automatic and punch press departments, and we hope very shortly to extend it over all our machines. From experience we find these departments are usually " bottle necks " when we have peak production to arrange for, but by this record we can measure our load and thus arrange night shifts or outside help, if required. It also provides useful data of the actual work done on a machine, and whether it is worth while keeping that machine if only used for a short period occasionally. We have actually thrown out machines by the help of these records. These remarks, so far, cover 75 per

cent. of the principal scheme of planning the production of a component, the other 25 per cent., I will gladly supply to anyone interested; in fact, should they so wish, I would be delighted to entertain them for a day at the works, so that they could study the system more thoroughly.

I hope so far I have not bored you with routine detail, and now I pass on to a few elaborations which might be of further interest. Take for instance the automatic bar machine department (Fig. 7),

FIG. 7.

consisting of 64 machines of different makes. We plan the orders in date sequence, as previously mentioned, but the control of the material is rather unique. You will notice in this picture a number of racks, each allocated to one type of machine, and on each rack the material is stored in parcel lots, against each order. Before the material is appropriated to the order, each rod end is chamfered on a small pipe screwing machine, the dies being ground taper (no thread of course), something like a pencil sharpener. This is a very quick operation, and is done by the storeman, but it is very interesting to note this supersedes the common method, in some shops, where the automatic setter, or feeder, does this operation or attempts to do it, on a grinding wheel. Our experience tells us that we save

setters' time, we have increased the production, cut out grinding wheels costs, and in addition a very big expense is saved in the direction of broken feed fingers and chucks, apart from the delay caused by either of these breakages.

By looking at the label on each material parcel, the full history is before you, and an occasional glance at these racks proves the efficiency of the automatic department. After the material is issued, this tag is returned to the planning section, where the date of issue is checked and should there be any delay, this is taken up with the responsible persons concerned. The foreman of this department already has his works order, material requisition, and production record card and by getting the drawing and operation list, he has the complete planning history and need ask no questions at all. On the one hand the tool layout with cams complete is ready for him in the tool store ; on the other hand, the material is pointed up and parcelled up and awaits his pleasure. What then does this foreman do ? All that is necessary is that he should do his job, and do it well.

Fig. 8.

We now come to the tool store (Fig. 8), a department of the utmost value to every organisation, but one which I am sorry to say is badly neglected in many factories. Can any works manager who allows his

tool store to be badly managed, measure up his losses through tools getting lost, and delays thus created. My advice on this one point is that a tool worth calling a tool is worth keeping well. This picture shows a portion of our tool store where approximately 100,000 tools and gauges are kept, all in proper order, ready for issue at a moment's notice. The control of this organisation comes under the chief inspector, because he is held responsible for the quality of production generally, and it is his duty efficiently to keep all tools and gauges, to produce that quality in a correct and proper manner. The tool inspection is also in this department, and all tools made in the tool room, or purchased outside, are not accepted until they have passed this section. The shop drawing office controlling the care and issue of all drawings, operation lists and assembly lists, is a section of the tool store. At the far end of the picture is shown a tool grinding section, which takes care of the sharpening of all tools, and our practice is that every tool and jig returned from use, passes through either this tool grinding section or the inspection section, before placing in store ready for the next issue. We can thus depend upon receiving a correct tool when application is made to the store.

Then we have what we call the finished store, appropriation section, which takes care of parcelling up all components into boxes ready for the assembly.

In the middle of each month we receive from our sales department, a programme of the requirements for the following month and from this information, we translate into works language, what is required. We have, you will appreciate, about two weeks to prepare our plans and our production office issues to the chief storekeeper, a schedule of the assembly call, in sequence order, regulated by the sales department, and linked up with the customer's demand. We endeavour to look two weeks ahead in this section, and should there be a shortage of any one or more components, or on the other hand, a store's mistake in connection with a quantity supposed to be in stock, we have a little elbow-room to make it up. In such a case, we issue to the sections concerned, a shortage slip and this conveys details of what is required to make up the complete set. Having done this we are able to prepare every component in complete assembly set order, ready for issue to the assembly department, on demand, against the time or date for issue according to plan.

In Fig. 9 we have a picture of one of many of our assembly belts, and in this instance we show you our motor car clock assembly. The chargehand controlling the belt has a copy of the programme as issued to the finished store, and he therefore knows what is wanted. In his case, his duty is to look ahead for two days and not two weeks as in the case of the stores. Should he foresee a possible hold-up within two days, he switches on the " red light," which is above the

assembly belt as shown. This is linked up with a series of lights in the stores, production office and also the works manager's office. You will thus appreciate that all are alive to the possible danger, and a move on is made to clear the line no matter what the obstruc-

Fig. 9.

tion may be. The feeder of this belt is the girl in the front who is surrounded by all components, stacked in proper order in the special containers shown, for the smallest parts. She also has a certain number of operations to do, such as riveting two or more parts together, cleaning with a compressed air pistol, etc., but working in unison with a time switch in the form of a light positioned in front of her, regulating the issue of each set on the belt. Notice also that this girl, and in fact all the girls, are provided with a comfortable chair. Why should they be? Why not make the working life of

everyone as happy and as comfortable as possible. This chair has a back to it, and is of oak. Therefore perhaps you will say : " What of the cost ? " This, my friends, is trifling when the proper market is searched. In this instance, I thought of the many ships being broken up, so I found after many inquiries, where I could buy some goods ships' chairs. There is no secret about these. They cost less than 2s. 0d. each. Further details on application. Each chair is positioned along the bench by a swinging cast-iron arm attached to each bench leg, the bench legs being six feet apart. This keeps the operator in a definite fixed position according to the assembly layout, at the same time minimising chatter which, as you know, takes place in the best regulated families where girls are together, and also among the men. This scheme provides a tidy appearance, and enables the floor cleaners to do their job in a much less time, thus saving money.

Along the whole length of the bench, each side, a foot rest is fixed to suit the operators. The assembly bench is built up of 4-in. × 2-in. channel iron legs, four feet wide, 2 ft. 7-ins. high. These are positioned six feet apart, and to these the chair arms are fixed. I forgot to mention that each chair is adjustable in height to suit the operator.

The bench top is two inches thick, suitable for a vice or any machine, and is covered with green lino which, from experience, we have found most suitable for the operators' eyes, as it is the most restful colour. Down the centre of this bench is a hardwood plank, about two inches above the surface, ready to take a conveyor belt if required.

From the bench just shown, the clock passes through the window into a timing section, and here we time 7,000 clocks, which are accommodated on sliding racks fitted with roller bearings in channel iron on the floor. These girls are attached to the inspection department and are distinguished from the assembly operators by means of a red armlet, which is a symbol of higher status throughout the whole of the factory. Great pride is taken in this distinction, as the rivalry thus created, benefits the quality of the work produced.

There are, of course, many conveyors in the machine shop, a scheme which is most successful. A belt conveys the component, after each operation, to the inspector at the end, whose duty it is to examine the quality before placing into transport boxes at her side. We find that the inspection expense is reduced to a minimum, and the component, when finished, does not lie on the floor by the machine, awaiting the pleasure of someone to move it on. Rough material only lies around the machine ; trucking costs are also reduced. Should there be anything wrong with the quality, the machine setter soon hears about it. He does not continue making

bad work ; or shall I put it—bad work is cut down to a very minimum.

The belt itself is of simple construction and very cheaply built up.

I have touched upon only a few planning ideas but before I conclude, I would say that we have not forgotten the planning of labour, which in itself, is a study on its own. It is no good planning a factory on ideal lines, if the labour side is left out of the picture, so we are gradually building up a school, through which we hope to initiate all our labour, before very long.

In conclusion, I wish to acknowledge my thanks to Mr. Gordon Smith, our managing director, for allowing me to give this paper, and to my assistant, Mr. Griffin, who has very kindly helped me in its compilation.

Discussion.

MR. LEWIS: I think the slides themselves are self-explanatory, but the lecturer might, if I may say so, have included one or two other points which may be of interest. One thing that strikes me— that this planning system can be a development that has gone on through the establishment of the factory, and it would be rather interesting to know the efficiency point of view—shall we say of how the production has been increased by this planning system. Another point that strikes me that would be also very interesting to know, and that is how can the firm determine what car manufacturers require? The point there is: we will assume there is a million-piece part being made per week. Does it not strike one that a million-piece part per week is going to be a big danger in loading the factory or the firm with a lot of surplus stock? The next thing that I think is also very interesting that we might know—would it be possible for the lecturer to give, say, a comparison of prices? That is to say, from the efficiency point of view of this new system, of prices of the actual article. After all is said and done, the accessory of a car is an absolute necessity, and as cars are cheaper, I take it the price of the article as sold to the manufacturer is considerably cheaper, and may one learn that price? It would be very interesting to quite a number of us present this evening to know the lecturer's opinion on a further point. I think it is common knowledge amongst engineers that one always looks to either German or American steels to produce a good article. Is he satisfied that he can get steels now of the same machining quality from British manufacturers as he can from American or German manufacturers?

MR. HAVILAND: In reply to your first question, Mr. Lewis, asking whether, in particular, an increase in production has been measured by the planning scheme illustrated, all I can say in answer to that question is this: that year after year for this last twelve years the factory, without making any extensions for productive purposes, keeps on turning out more and more, and when I say that the output over the past five years has trebled itself, bearing in mind that always the factory is working full time, I think that in itself is significant that the planning scheme is sound. You also ask how it is possible to cater for the car manufacturer's requirements, colossal though they seem. There are many gentlemen present who are in the motor car industry, and they know just as well as I do what a difficult matter it is to budget for what is required. It is almost impossible, but we have, I think, a very good sales department, and each month three of us get together and we budget what is required, not for April, but for May and June. Sometimes we come a little

adrift, but nothing to worry about, and we are thus able, in many instances, to meet a telephone demand in a morning and ship it by passenger train in the afternoon. Mr. Lewis asks rather a ticklish question when he starts talking about prices. I am not here to divulge any prices, but again as there are many motor car friends here, they are always, year after year, wanting reductions, and that in itself is an assurance that our prices, year after year, have to come down. Were it not for some efficient planning organisation, I can assure you that we should not be able to meet that request. The next question was British steels. I don't know whether you mean tool steel or whether you mean mild steel. Well, with regard to free cutting mild steel, some years ago we had great difficulty in finding a suitable supply in this country, but during the last two to three years I am very pleased to say that we have suppliers in this country whose products are equal to any American products and if any gentleman would like details I shall be pleased to furnish them.

MR. R. H. HUTCHINSON (Past President): I had hoped that I should have been able to sit quiet for a few moments and hear how other members in the room approached this discussion because, frankly, I find it very difficult to discuss the paper so admirably presented by the author. The way the author has taken us for a trip round his works this evening, verbally and with lantern slides, is excellent and very admirably presented. He started at the beginning and took us right through, and by the time we got to the end we were just ready to go into the canteen and have a cup of tea.

I may be mistaken, but I thought that the title of the lecture was "The Functions of a Planning Department," and in view of the varied nature of the subject, very wisely, restricted to a particular product—in this instance instruments. Well, I listened from the beginning to the end of the lecture for some information about the functions of the planning department. We had, to start with, a lot of forms put up on the screen: very nice photographs, very good lantern slides: but, after all said and done, you do not discuss the functions of a lathe by trotting out a few of its cutting tools, and I do not think that those forms have anything to do with the functions of a planning department; they are merely analogous to the lathe cutting tools.

Perhaps the author will tell us a little more about the cards used. For instance, where these cards are filled in, when they are filled in, how they are filled in, from what they are filled in. One case in particular was a time table for new products which caught my eye. The first item was I think "drawings," "date wanted," "date completed": the next was "raw material ordered" and "date wanted," and "date completed," and so on. It is all very nice, of course, if one can get the whole of the drawings out with no modifications of the drawing and you can sit down and make out all the orders. These things all sound so delightful when described

in this way, but when it comes down to actual practice, there are so many fringes which enlace with each other, and do get so tangled up.

One interesting point not really concerning the planning at all was that the tool inspection was under the chief inspector. I do not agree with this and was rather surprised when I heard it. I consider that the chief inspector should be perfectly free from responsibility of production; he must be responsible for pulling up bad production as quickly as possible after it starts to be made, so as to keep the scrap to a minimum, and I think the conveyor taking the work promptly and directly from the machine to viewer is for that reason very admirable, but to make the chief inspector responsible for the upkeep and accuracy of jigs and tools, and the grinding of cutting tools, seems to me contrary to his duties and likely to warp his outlook on the work he has got to inspect. It seems to me that it might act in the wrong way, and I suggest that whatever the product or wherever the works, it should be most emphatically laid down that an inspector shall not be responsible for the functions of production in the slightest degree, and I am a little doubtful about the wisdom of putting the tool stores and various other functions under the chief inspector. It may work but it is certainly neither wise nor orthodox.

The system of coloured lights—well, of course, that is a very good way of indicating shortages. I have heard that the particular works we have had described to us to-night sometimes looks rather like Piccadilly Circus in the evening time! With regard to the increase in production traceable to this planning system, I listened for the answer to that question with some anxiety, but after all is said and done, I suppose really you cannot say that production is increased or can be increased in the circumstances by the planning. Planning must follow the requirements of production, because you can't plan for anything until you know what you have got to plan for, and it seems to me that production is really increased by the sales market and not by planning.

If I have appeared critical in the few words I have said it is not because I am ungrateful. I have been extremely interested, and I congratulate the author on the manner in which he has substituted a most interesting description of his works for what he evidently realised was an almost impossible job when he started to write his paper, namely to describe the functions of a planning department. I have been critical in the hopes of stimulating others to debate, because I do think it helps other members—especially the younger ones—onto a line of argument and discussion, and that is the only thought or desire that I have had in my mind this evening.

Mr. Haviland: First of all I might say that Mr. Hutchinson, although he does not know it, perhaps, is an old friend of mine,

and when I saw his face beam in the door to-night I turned round to Mr. Hales and I said : " Now I'm for it ! " I think he has let me off very lightly, and I thank him for these remarks, somewhat critical though they seem, yet as he says, he has done it for a purpose. Now, he has said such a lot that I am a little at a loss as to what I have to answer, but he mentioned that I did not specify where this planning scheme was done. I mentioned in an earlier part of the paper that we did not specialise in a department in the same way as some firms do—that is, a department called the planning department. Our particular industry does not call for that specialisation, so we link it up with our estimating department, and we have found from our experience that it works very well indeed.

The criticism which I value very much is regarding the combination of the control of the tools store with the chief inspector. I quite agree with Mr. Hutchinson's remarks. It is food for thought. But in the past I have had a very capable chief inspector whose desire at all times is to produce the "goods," and having that confidence which has been working for many years, I have not thought fit to make a change. All the same, I agree with Mr. Hutchinson's remarks, and I know such a system would not work in his business. I was rather amused at the Piccadilly reference to our lights. I haven't really noticed the resemblance myself, but whatever is said, these lights bear fruit—of course, I know he means that as a joke. Mr. Hutchinson only could say that, so nicely was it put.

He also mentioned about the records of increased production. Apparently I did not make that quite as clear to Mr. Hutchinson as I did to Mr. Lewis. We have definite records kept of how the production has increased through this organisation. The details, of course, I cannot give you here as it would take too long.

Mr. Groombridge (Member of Council) : There is one point I would like to deal with, and that is raw material. I am not getting up to criticise, but it does prove to me that to be able to work on such a close planning and delivery date you must be purchasing material many months in advance of your production requirements. Undoubtedly with your products you must have many special materials. How do you get on should you suddenly decide to stop a product for which special material has to be purchased ? Are you overstocked a lot with that material ? How do you overcome that difficulty ?

Mr. Haviland : In reply to that question, I indicated that at our sales conference, held monthly, a fairly accurate budget is mapped out as to what is required, and we base our programme on a three-monthly quantity. Raw material which might be special, should there be a hold up or a cancellation, is such a small parcel in the majority of cases that we have to write it off. It is not like an item

such as cylinders or crankshafts. When you are making an instrument such as has been passed round, there might be some special material in it. Take that diaphragm—that is special material, but in a case of that sort if we had a hold up by one customer that material would be used for some other customer on a similar instrument. The same with the majority of our products. If one customer holds us up, ten to one the material will be used up on some other customer. It is not like manufacturing : instruments which are totally different, and I always consider it is much easier than manufacturing motor cars or aeroplanes, or similar articles. Then it is very serious indeed in a change of design.

Mr. C. B. Northey : At the last meeting of the Institution the question of education and training the embryo engineer was raised. I want to raise now one or two points from that angle, because personally I view planning as an important department of the factory, and I can tell you that some of the other Institutions are also waking up to the fact that planning a works organisation is becoming an important part in the training of their Associates and members. One Institution in particular is cutting out what is known as economics, and is going to insert, in 1935, works organisation, etc., and I want just to raise a point there for you as to the education of planning engineers. What would you suggest should be our line of development ? As Mr. Hutchinson has said, planning is a most difficult subject to teach. I should like to know the lecturer's view on the question of the education of planning engineers : whether we should draw them from the factories, which, by the way, is my own opinion, or whether they should be included from what is known as the academic side of engineering. I was rather disappointed that Mr. Haviland did not show us exactly how a certain product or piece was planned from the office and through the shops.

Regarding the belt conveyor system, which was very interesting, particularly its simple design, we could not see very well from the slide as to how you would check this against the actual operator on piece work. It appears to me that it ought to show some sort of label on the work or some designating mark which the inspector might be able to check against the operator from the point of view of payment. I was rather interested, also, in the fact that there was not a separate planning department, and it appears to me that it would be a difficult situation in some works. It may be all right in Mr. Haviland's works, but I am afraid it would not do in all works. It seems to me that it should be attached to the production department, because surely the production engineer is the man who is responsible for the planning of his production department not the estimating department. If you are going to attach it to a department it should surely be attached to the production and not to the estimating department.

There is a lot to be said for the use of lights similar to those shown, as they do convey information quickly—and save a considerable amount of labour, running backwards and forwards to offices with information that things are happening down in the works, particularly if the offices are away, as they often are, from the production departments.

MR. HAVILAND : Your first question was one which I personally have very near at heart, and that is the training of the future engineer. We all have to play a big part in training the future engineer. I realised that many years ago, as far as my factory is concerned, and when I say that 27 men who hold executive posts under my control are men specially brought up, that speaks for itself. We have a system which is one whereby we expect every boy who joins our company to attend evening classes. We have between 80 and 90 on our books for the past session. We are linked up with the education authorities, and each month we have a report of the attendance and the progress of each boy at evening school. We have also a system of getting information from the foreman concerned as to the behaviour and ability and progress of each boy. That information is monthly sent from my office (sometimes with a nice word of encouragement to the boy) to the parents, so that the parents are linked up with us in encouraging their sons to become better men. That little link I found necessary because I wanted to give the poor boy who has not got what I should call a good home, a chance of receiving a word of praise from his father or his mother, which would go a long way, and from the letters that I receive from these parents, it is worth while. We therefore get information, and we are able to pick out from the night school reports and from the firm's report the qualities of the boys, but we go further than that because we found, and quite naturally so, that the reports from the evening schools were somewhat exaggerated. The headmasters always liked to give a good character to the boys. So we adopted a system of having an examination once a year—Midsummer—an examination for which, with the co-operation of the education authorities, the boys sit a few nights, and from that we take the result and go through it picking out our bright boys. Now here we have the fellows ready for placing in any position which becomes vacant. We are also linking up with the secondary school authorities and we are picking up some very brilliant academic students. With the training they have at the school and with our training, we hope to make them into good men.

Now you ask how do we keep a record of the work as it goes down the belt ? Each operator in the machine shop has his particular job to do, and as each job is different it is very easy to pick it out.

You asked why attach the planning to the estimating department —why should not it be under the production engineer ? The simple reason is we have not a production engineer.

MR. BROOKS: The question of planning has always seemed to me to be extremely difficult. Factories divide themselves into two classes mainly: one like Mr. Haviland's factory where a certain component or a piece is made for sale, and other factories in which everything that is made in the factory is previously ordered, and a factory such as that may make things which are never to be repeated again. Well, my first experience of planning was in a factory of the first sort, in fact it was typewriting machines. It was decided in this particular factory to increase from 50 to 200 machines per week, so the works manager said he must have a planning department. He had one; and through some mischance I happened to get the job of being the person in this department who had to take charge of the automatic department. I made a schedule and decided how many automatics we should need above our existing number, and the net result was that when the various schedules began to go into the shop the auto foreman used to run into the office and say they would not work and I had to argue it out with him in the shop. In the end I was doing half the planning and half the auto foreman's job, so I moved from there. The next time I was the auto foreman and someone else did the planning, and the curious thing about it was that this time, every few days, I used to have to go up to the drawing office and ask for work for such and such a machine. They did not give me enough work.

Well, it is quite obvious, coming down from all that, in these days the cost of the machine and maintenance is the biggest factor in production. Machines are becoming more and more costly and more and more automatic, and to my mind it seems to be the chief thing to keep a machine working, or, alternatively, to be sure that you do not buy too many machines for the work. I suppose in order to get over that difficulty the proper thing is to employ a man for machines who knows his job. If this is so, can a planning department, which obviously must have an expert in it, be reconciled with the expert on the machines, because, quite candidly, I have never seen it done successfully. Supposing you give the control of all this to the estimating department—naturally, the estimating department do not want to make mistakes, so they are always a little on the safe side: the result is that you may buy, in a large business, many thousands of pounds' worth of machinery that is no use to you, and on the other hand if the estimating department are a little optimistic you may find you have not got enough machinery or enough money to do the job, and it seems to me almost impossible really to strike a dead level so that the thing comes out exactly right. Either machines are standing, or you find a factory always having to work overtime because they can never keep up with the requirements laid down for them. It seems to me that the best method of getting a job right is to put a man in charge of the par-

ticular machines in question—absolutely the right man for the job—and then let him be his own planning department or his own representative in the planning section. I should like to know what Mr. Haviland thinks of all that.

Mr. Haviland : Mr. Brooks, I know you as an expert on automatics, and I am not for one minute going to tell you your job. As you have made automatics your speciality through life you know more about it than the planning department, but we think this that the capacity of the machine is determined by the cam layout, and having that information it is a simple matter to plan any group of automatics. By doing that we have proved conclusively without any doubt that the scientific way of calculating the cam times has increased production which heretofore has been controlled by the automatic foreman with his idea of laying out the job. We have definitely proved this, again and again by basing our calculations on the advice of the machine makers. Who is better served with problems than the machine maker ? Surely, any sensible person would put their problems up to them for advice ; so why be foolish and not take this advantage. Unless we daily get these problems we get out of date. That is my feeling about the automatic foreman, more so than in any section of the machine shop.

Also, we have proved that by sending inquiries outside to such firms as yourself, you are a long way out with your costs which I think clearly answers your question.

Mr. Hales : I am pleased that our lecturer has dealt with the subject of planning in the broad sense. I would say that his answer to the functions of a planning department in an instrument factory, as such, is in the negative, but he has dealt with the functions of planning in a particular factory and in that sense he has covered the subject so far as that particular factory is concerned.

My own opinion is—I am now speaking of estimating being bracketed with the planning department—in estimating you must start with someone having a practical knowledge of the operations and the planning of those operations, as I really consider it is impossible to get out an estimate unless you go through the functions which, in a planning department, are carried out by that department. In this sense you have got to layout your operations in sequence order, and you have got to know what are the correct machines to put that job on. You must know what are the best tools to put on those machines, and in that way arrive at a production time factor, from which your estimate is ultimately based. I think the functions of a planning department in various factories—we know in the larger factories they have a department under that name—work very efficiently. To my knowledge there are eminent engineers and production men performing the functions of a production engineer under the name of senior foreman, works manager, superintendent,

and so on. It would appear to me that we cannot lay down any law to suit every factory. The great thing is to get the right man in the right place. In other words, if in Mr. Haviland's factory it would appear apparent we got a first-class man in our inspection department, very good, then you put the responsibility on to him beyond what one would do in another factory with a different calibre of man.

Mr. Haviland has dealt with planning in a broad sense, and from that point of view he has given us a lot of interesting information as to how they have improved production in their factory. I would like him to go a step further. There are many hundreds of factors which mean success or otherwise. We have heard the reference to the comfort of the workers : it was good ; he has also made reference to the way ability is recognised ; I would like him to tell us how, in a factory of their description, they arrange for getting the right type of labour, because their personnel will change from time to time : they will have busy periods when it means employing a lot of new hands. I would like him to tell us how they deal with that.

Mr. Haviland : The last paragraph of my paper mentioned that labour played a very important part in the planning of any factory. Labour is not engaged by the foreman. It is engaged by my assistant every morning at 8-30, if required. My assistant has been with me for many many years : he has held positions in many parts of the factory, and he knows equally as well as the foreman what labour is most suitable for his department.

Some years ago when we fixed up that scheme, I said to him, "Let's try and get a better quality of labour, more refined, smarter and cleverer," and I am pleased to say we have been successful. My assistant has tests that he gives the girls when they apply for a job—simple tests—but we are going a step further than that. We are at the present moment allocating a part of our assembling department for a school, and I am appointing someone for the position of training the operators, because on some of our work it takes at least four to six weeks to get the operator down to a certain operation.

For instance, one little test is a piece of rag on the floor, put in the way of the girl to walk over : if she walks over it, that is a point against her ; if she stoops down and picks it up, that is in her favour. Give a girl a few screwdrivers and a simple assembly in front of her—watch which screwdriver she picks up. She might pick a very big screwdriver to get a little screw out : that is a point against her. Watch how a girl holds the work to use that screwdriver, and such things as that. Quite a lot of them—little inventions of my assistant.

But you might say that is a very unfair test. What about the youngster that comes along, or the girl that has never been in an instrument factory before ? Well, you have to use your discretion in

a case of that sort, and from the questions you ask the girl you can make your mind up whether she is going to be suitable or not, but as I say, we are not satisfied with that. We appreciate that the tests we give to girls—the time we allocate to them—are not sufficient to weed them out. We are going to put them through this school, and after a week or two we shall then judge much better whether they are going to suit us.

MR. BEADLE : I would like to ask the lecturer the quantities that he deals with in each of his products. Is it dealing with several thousands or is it merely hundreds ? I notice he has got 13 forms to plan this job. Is this an economical form of planning ?

MR. HAVILAND : In reply to that question, the bulk of our production is in thousands, but we stick to one system unless we have, say, half a dozen to make, and that half a dozen is pushed through the experimental department. If we had 100 to make we should put it through this system just the same. We know that for such a small quantity it is cumbersome, but you cannot run two systems in a factory.

MR. PUCKEY : Possibly because I attended a lecture yesterday evening on the subject of budgeting, I am perhaps rather more interested in that aspect. Our lecturer made an all too brief reference to budgeting and mentioned that once a month three of them got together and decided on the budget for the forthcoming three months. I should like to " listen in " to that select circle for a little while. Do they budget on the material or on the prices factor ? If they budget on the material, I should imagine they would have to go into the matter very deeply indeed, taking every sort of material in the factory. If they budget on money, then how is it that that money is portioned out to the various material they have to purchase ? Secondly, there must be a considerable number of spare parts in the factory beyond their various assemblies, as parts alone, and I should be glad to know whether you work on a maximum or minimum basis there, keeping a certain minimum in stock all the time. Thirdly, as you work on the load factor of the various machines, indicated by one of these charts in the booklet ? I assume you must know very accurately the time taken to do all the operations. That, I assume, is calculated by the estimating department. Do you verify times before they are put into practice in the shop, and if so, how ?

MR. HAVILAND: Your first question was our deliberations at our monthly conference. The sales director is in the chair, and the chief warehouse storekeeper is also there, along with myself. The question of prices and material is my affair—the sales director at this meeting is budgeting quantities. He says that so and so wants so and so by so and so. He has his delivery instructions before him all mapped out by his assistant, and he goes through the customer's requirements

in detail and tells me what is wanted. You mention 5,000 live assemblies. Five thousand live assemblies means that 5,000 are not floating through the factory at the same time. Some of that 5,000 might be called upon, but the warehouse assistant has his records there, and he prepares what his chief has to go through and approve.

I should think we go through at least 2,000 to 3,000 live products in an afternoon, and having all the information before us, it is not difficult.

With regard to whether we use a maximum-minimum stock in view of so many parts being common, there is what we call a master card, and down its side, the third from the front on the left-hand side, it says "assembly code." On one I have here—25224—there are 500 wanted in March and 500 in May of that particular component 25917. Sometimes for one component we have as many as half a dozen cards filled up, and from the sales call we have such quantities as 500 for March and so on.

If the work is not produced to time according to the production card, that is returned to the estimating office, and if there is a big difference between the completed date and the actual date when this card is returned which represents its completion, it is taken up. The date that it is completed is recorded on the progress record card, and it gives you an indication of the position of that job should you wish to know it at any time.

Mr. Puckey: That does not quite answer my question. You are talking about the time taken to complete a contract. What I am getting at is the time taken for each operation. There must be certain times laid down per 100 or per unit, and I assume some endeavour is made to work to them. Well, is there any difficulty in working to those figures that are estimated by the estimating department?

Mr. Haviland: Well, the foreman has got his job; he has got his piece work price: everyone is on piece work. The foreman's job is to see the piece work price is fixed and before that is put on the department it is all agreed that is correct. If the operator does not work to that time it is a loss and it is shown on her piece work earnings, so at the end of the week, if you have a slow operator not working up to the correct scheduled time, it indicates lower wages. When we make the planning out, the planning is made to the estimated time. When that is a new job and obviously not to the actual time because the job is not then on the machine, we have to make adjustments to the layout if it is considerable.

Mr. Ferguson: I should like Mr. Haviland to tell us whether, before an estimate is given for the manufacture of a component or unit by the estimating department, the foreman of the departments concerned are consulted for their views on the suggested sequence of operations and the design of the necessary fixtures, tools, and gauges; and if at a later date any change is made in the original

method of manufacture are the foremen consulted or is the change made arbitrarily by the drawing office or estimating department, bearing in mind that the company has no planning department functioning in its works.

MR. HAVILAND : The operation list is prepared in the planning department, in consultation with the chief draughtsman, so the chief draughtsman and that department work as a team together. The jigs, and all tackle that is required for producing that component, are linked up with the operation list and it comes under that discussion. If a change is required after such careful planning, and is necessary when the job gets in the shop, the operations are altered just in the same way as a drawing is altered, and automatic changes take place both in the drawing office and in the estimating and planning department. It is just a routine practice to switch the operations round to the job, after due consultation with all concerned.

On the motion of Mr. G. Still a cordial vote of thanks to Mr. Haviland was adopted.

A TALK ABOUT STEEL.

Paper presented to the Institution, Sheffield Section, by T. W. Willis.

SO much has been written and talked about steel that if it were all collected together it would form a very extensive library of its own, and to read a paper on it to-day without trespassing on what has been said and written by others, is practically impossible. Perhaps, however, you will forgive me if in opening my subject, I delve for a little into its early beginnings and ancient history.

Steel in the old days was understood to be an alloy of iron and carbon with a top carbon limit of approximately two per cent. ranging down by degrees to round about 0.50, and doubtless the limits of the temper range were much wider than is looked upon as good practice to-day. The beginning of the use of steel is usually attributed to the Chalybes somewhere about the time of Homer, who records " that the art of hardening steel consists of heating it and immersing it suddenly in cold water " and it is also on record that the Chalybes produced their steel by fusion, and as the bulk of the steel made to-day is produced by fusion, it rather goes towards proving the old saying that there is nothing new under the sun.

In fairly recent years the use of nickel as an alloy of steel has had a great vogue, and the results obtained from its use have been of great value in many of our varied manufactures, but the use of nickel in steel is very ancient although its method of production varied considerably from the practice obtaining to-day. The main principle was, however, the same, but the use of it was very rare and confined to the making of swords and daggers.

The method of making it is recorded as using lumps of what were termed " lightning iron " or what we know as meteorites, which were a combination of iron and nickel and fusing them with " common iron " which was possibly what we know as pig iron, and the " mix " is quoted as two parts of lightning iron and one part of the common iron. The lightning iron, I should imagine, had had all the carbon it might have contained burnt out, or oxidised out of it, and the carbon to make it into steel would come from the carbon in the common iron, and the carbon in the resultant mixture would be in the region of .40 to .60, but this is pure surmise on my part.

However, it is on record that the swords (sabres ?) made from it were of a fine temper and very elastic. Another process that is

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25th April, 1933.

very old is that of case-hardening. One of the processes was cementation by the use of wood charcoal, a process analogous to what is known as " converting " which is carried on in Sheffield at the present day, and provides the blister steel from which genuine single and double shear steels are made.

Another process of cementation used by the ancients is said to have consisted of forging such things as axes and the like from wrought iron roughly to shape and then immersing them for a short time into molten metal of high carbon content until they got a penetration of carbon from the metal and possibly a skin of carbonised iron, afterwards roughly dressing them into shape again then re-heating them and quenching them in cold water. To me it seems to have been a very crude process and unlikely to give anything like an even surface of hardened material, but we never can tell what results may have been obtained by practice and craftsmanship.

Coming down to nearer our time, a few generations ago the bulk of tools, springs, etc., were made from blister steel, which was bar iron, converted by the cementation process into steel. This steel was cemented so that it had either a small depth of carbonisation or the process was carried on until the bars became " steel through " or even supersaturated to something like a carbon content of 1.60.

The bars were sorted out into tempers by eye. So accurate were the " bar sorters " that they could get very close results every time, judging entirely by the appearance of the fracture.

This selecting of tempers by bar sorters is carried on in Sheffield to-day. These converted bars were afterwards hammered, tilted, or rolled into various sizes and sections, but their sectional area was very much limited. This converted bar is also made into what is known as genuine single or double shear steel and the process is, that bars of correct shear tempers are broken into pieces about 16 inches long, these are drawn out under a hammer into smaller bars, and then several bars are piled over one another, and the end of this pile is finally wedged into an iron hoop with a handle attached to it, the free end of the pile is raised to a welding heat and then welded together into a square bar, then the handle is detached from the other end of the piled bars and welded just in the same way as the first end. In this state it is termed " single shear steel."

Afterwards, if what is termed " double shear steel " is needed, the bar obtained by single shearing is broken in two parts. One is put on the top of the other and again welded together. After which either the single shear or the double shear may be tilted down or rolled down to any required dimensions within its compass, and for many purposes to-day " double shear " cannot be excelled. I may here remark that many users confuse this single and double shear steel as meaning the steel to be used for shear blades for cropping shears, but this is not so and when steel is to be used for shear blades

the term shear steel should not be used but shear *blade* steel, or steel for making shear blades. After 1740 when Huntsman brought out the crucible steel process, the aforementioned blister steel was sorted out into different tempers, i.e. pieces containing various amounts of carbon. This was easily broken up because in the state of " converted bar " it was very brittle and could be broken into pieces from two to four inches long, and every piece was sorted by the bar sorter, so that when melted a predetermined temper or carbon content would be found in the resultant ingot, the crucible charge being made up of pieces broken from bars converted from a mixture of different brands of bar iron and what is termed " physic," the combinations of which were known by experience to produce the quality and temper of steel most suitable for the ultimate purpose for which it was to be used. The original bar iron varied in quality and purity and even in method of manufacture. The cost of these bar irons varied with their quality and so accounted for the varying qualities and prices of what are known as straight carbon crucible cast steels, and sixty years experience has taught me that if really high quality crucible steels are desired, and customers are prepared to pay for them, there is nothing superior to straight carbon tool steel made in this way to-day. Crucible steel, however, is not suitable for many purposes for which steel is used. To-day we have many more steels at our disposal specially suitable for their different uses, and made by different processes.

In very early days of steel melting, the crucible process was the mainstay, and where large sizes were needed, large ingots were made by simply pouring the contents of many crucibles into one mould, the ingot being forged down under either steam hammers or metal helves into blooms or billets, and the subsequent processes were as those still in use. There was also puddled steel, which one hears very little about. The Bessemer process was more or less in its infancy, then came the Martin process, and the Siemens Martin process, all of which were acid processes. Then came basic Bessemer and basic Siemens, and now we have various electric furnaces each of which produces its own characteristic steel. Steel to-day may be classed as an alloy, the essential contents of which may be taken as iron and carbon together with different percentages of silicon and manganese, and also present as impurities, certain small percentages of sulphur and phosphorous, and this is generally styled a straight carbon steel. In addition to this, steel has become a much more complicated alloy than straight carbon—wolfram, also known as tungsten. Chromium, nickel, molybdenum, vanadium, cobalt, uranium, titanium, copper, tantallum, etc., and also high silicon steels up to three or four per cent. silicon, high manganese such as the 12 per cent. alloy known as manganese steel, all of which have their respective uses commercially and their merits and de-merits. Therefore, we have for commercial use :

Straight carbon steels.
Chromium steels.
Chromium, nickel steels.
Carbon vanadium steels.
Manganese steels.
Molybdenum steels.
Nickel steels.
Nickel vanadium steels.
Chrome, vanadium steels.
Chrome, nickel, molybdenum steels.
Manganese, molybdenum steels.
Molybdenum, chromium steels.
Molybdenum, chromium, vanadium steels.
High silicon steels.
Silicon manganese steels.

Also the various rustless steels, which usually contain chromium and nickel in various combinations such as the 13 per cent. ordinary rustless the 18/8 corrosion resisting alloys, and also heat resisting alloys..

Taking the older of the fusion processes first—the crucible melting process is the one by which nearly all classes of steel can be made and where high quality is concerned it is the best ; but inferior steels can be and are made by the crucible process depending upon the grade of the raw material used as the base of the charge. The high class crucible steel maker uses high class expensive charcoal irons as the base material for his charge and by the resultant high quality of his products commands a high price for them not only because of the high cost of his base from which his ingot is made but also because of the care exercised in the subsequent processes from the ingot to the finished bar and the careful examination between each process during which examination any material that shows faults is ruthlessly scrapped. In the cheap grades of crucible steel not only is the base material of the steel inferior in quality, but the same care and ruthless scrapping does not always obtain, and some of the subsequent processes may even be omitted and to the uninitiated who is unaware of all this, it is often a puzzle to him why steels of apparently the same analysis vary so much in price. Within certain limits, analyses of different steels may be fairly identical but the *quality* will be far from being the same. To use the expression of the old Sheffielders, the commoner qualities of steel are " short of guts." From the moment of having gone cold and before allowing the ingots to be further manipulated the process of discarding commences, the top ends of the ingots are broken off and from the fracture obtained the experienced examiner can tell not only the " temper " (carbon content) but whether the ingot is a sound well-melted one, also whether it has been teemed too hot, too cold, too fast or too slowly, and, in the higher classes of crucible steelworks, those ingots that are not exactly right are scrapped right away. Reverting to the " temper " of the steel, in the old days the steel maker judging from the fracture of the ingots, divided his temper ranges into six and the temper ranges were numbered from one-six, but as experience was accumulated, half tempers came into use and tempers became as a rule, 2, 2½, 3, 3½, 4, 4½, 5, 5½, and 6, and the experienced man can pick

these tempers so closely by eye that when they are checked over by subsequent analysis they are very rarely found to be incorrect.

Occasionally, very experienced men will dispute the result of a carbon analysis and very rarely are they found wrong, provided always that they are thoroughly experienced. In my early days of steel making, analyses were not only very, very costly, but much time was wasted and they were not so correct as temper picking by eye and therefore temper picking by the eye was the universal practice. The range of these temper numbers is from a carbon content of 0.60 up to 1.40 with a certain tolerance range in points of carbon for each temper of roughly 10 points, but in some cases closer than this down to even seven points. By experience gained through trial and error the old steel makers found that the lower carbons were suitable for shock tools and the medium tempers for general tool work, while the higher carbons were suitable for cutting tools, and by following up the results obtained during the actual working of the tools they found not only that certain tempers of steel were suitable for certain classes of tools but that the half tempers or even a variation of whole tempers were most suitable for different sizes of the same tool. And that even different blends of the raw iron of the charge were more suitable and produced better tools than if made up of one make of raw iron. This was the result of hard practical experience, a great deal of thinking and even profiting from the result of failures.

I have expatiated on these questions of quality and temper to show how they affect the user of tool steels because nowadays there are firms who judge the cheapness of tool steel by the lowest prices per cwt. or per lb. at which they can buy it. It is all very well for the purchasing side of a business to be able to assume that they have saved so and so many pounds sterling per annum in the purchasing of their tool steel, but have they really saved it ? The man in the workshop is the man who really knows ; just let us look things fairly in the face ; a few shillings per cwt. are saved in the actual cost of the steel by purchasing cheap tool steel, which is somewhere under a penny a pound, a few pence in all the piece of steel to be made into a tool. Often a few pounds worth of work are put onto the piece and the result of the saving in first cost is either an indifferent tool or a waster. Now where *is* the gain ? Very frequently, as I see almost daily steel is ordered simply as " steel for tools " and the sizes and sections are given. Now " tool steel " is a general term, and although the sizes and sections will often guide the steel manufacturer as to the purpose for which it is to be used, they are a long way from being an infallible guide, therefore when ordering steel the user should furnish the maker with as much information as possible as to the precise purpose for which the steel is to be used. The maker is not seeking to pry into the users' business but is needing the information so that

he may supply the most suitable temper and quality which his long and varied experience has taught him, will with correct subsequent treatment by the users, give maximum result. In other words, if users will do this they are not only buying steel but service is included in the price.

Despite all the care and experience put into the making of the steel, trouble will and does at times arise in the working of tool and other steels and the first natural impulse is to blame the steel, the operative feels that he has done his part of the work correctly, carried out the instructions of the steel maker, yet here is a bad tool or a waster and trouble.

Let it be here admitted that despite every precaution and rigid inspection, it is possible for a defective bar of steel to get out of the warehouse of a steel maker, but it is a very rare event and the manufacturer who is wise and values his reputation on seeing such a bar, will frankly admit its fault and replace it.

When users of steel have got over their first impulse to blame the steel, do they go further and consider the almost innumerable causes that may entail entire or partial failure ? I fear not. Some of them do, and often success is their reward and valuable experience is gained. Others do not. Some push the spoilt tool into the fire and thereby obliterate any of the traces of incorrect manipulation and then return it to the steel maker and ask for his explanation of the cause of failure. Others send the tool back to the steel maker just in the state in which it went wrong and give him as fair an account as is possible of the procedure that took place with this particular tool and ask for his help. When users cannot diagnose for themselves the cause, this is by far the wiser plan, because the maker of high class tool steel has usually well equipped research laboratories and staff, and in addition has also experts in the manufacture and use of steel, whose long experience has taken them through most of the difficulties which have been encountered. These laboratories and experience are at the service of the user, for two reasons, one for the manufacturer to prove the quality of his material and the other to help the user to get the best out of it and also to advise him how to avoid such unfortunate happenings in future and this confirms my previous remark that when buying steel the user is buying service with it, a matter often overlooked.

While on this subject just let us look what sort of information is needed in order to locate causes of complaint and how it can be best imparted to those responsible for the diagnoses thereof, and the subsequent rectification.

First and foremost is " Has the right quality and temper of steel been used ? " because the ignoring of these essential precautions is the cause of more trouble than any of which I am aware. If called

" tool steel " and the size is right for the purpose, steel is frequently made into tools for which it is most unsuitable. Steel becomes mixed in store, and I have known high speed steel sent out of store to make a carbon steel sate, and on the other hand I have known a piece of 1¾-inch square three temper (carbon .80 to .85) given out in the place of high speed steel from which to make a turning tool. This steel, having been given the high heat treatment was burnt rotten and the steel blamed.

In investigating similar complaints to the foregoing a couple of seconds on an emery wheel and the use of the spark test would at once reveal the cause of the failure. Should anybody present be unfamiliar with the use of the spark test, I may here remark that it consists of applying the piece of steel to a fast running emery wheel, preferably on the side of it, pressing it against the wheel until such pressure has been given that will cause sparking. If the steel is applied at the right angle for the purpose it will throw off a stream of sparks. High speed steel will throw off dull red sparks and the stream will be dense and the sparks will give off few or no explosions in their passage through the air. Steels containing wolfram in small proportions and highest carbons will throw off two classes of sparks, one a line of the dull red sparks and also a line of the bright sparks, the more brilliant the carbon sparks the higher the carbon content of the steel. In the case of the straight carbon steel there will be no dull red sparks, and the bright sparks thrown off will give a fair indication of the carbon content of the piece. As the shower of sparks flies off, at a short distance from the starting point, the sparks will explode, and each little explosion will throw off another line of sparks, and from the quantity of explosions resulting from sparks given off from explosions resulting from explosions, it is a fairly easy matter to form an opinion of the carbon content of a piece. The more resultant explosions from explosions the higher the carbon content will be. This is, I admit, a rather crude way of putting it, but to those of you who are interested I recommend you to take some pieces of steel of known carbon content and a piece of iron, go into a darkish room (the darker the better) provided always there is just sufficient light to prevent you getting your hand mixed up with the emery wheel and trying to obtain sparks from your fingers instead of from the steel. About an hour's practice coupled with careful observation of the resultant sparks, will soon enable you to prevent such cases as I have mentioned.

I would suggest you first take the piece of iron and secondly the piece of high speed steel and familiarise your eye as to the difference between the iron spark and the high speed steel spark. Next take the lower carbon steel pieces in the known order of their carbon content, beginning with the lowest and going in turn on to the

highest and, after having familiarised your eyes with the different classes of spark, mix up all the pieces and take them again at random and see how nearly you have arrived at judging results. You will have had an hour's interesting study and have considerably educated your eyes. This, however, is a digression, but a profitable one, from my remarks on the investigation of causes of complaints, so we will " return to our muttons."

The steel or tool needs examination for self-evident defects. " Seams " " laps," " pipe," and " fin " will occasionally be met with. These are faults of manufacture and such steel should never have been allowed past any " overlooker " in the steelmaker's works, who is worth his salt, but in this examination pipe must not be confounded with " bursting " or " churning " which are caused by various means such as not heating through. Continuous rounding up under flat faces " seams " and " roaks " should not be confused with cracks. Forging cracks may be due to want of proper reheating; putting a piece of cold steel right into the heart of the hot fire is a prolific source of such cracks. Forging cracks may also be produced by forging when too cold, while hammering in the " blue hot " stage has filled many good tools or pieces of steel with surface cracks. There are also cracks in a finished tool which may be due to grinding. Unequal heating, improper quenching; one noticeable case is that of ring cracks in flat blades which are caused by overpressure at the grinding wheel, the flow of water during grinding was kept away from the point of contact, the patch had got hot, the water again came into contact and the ring cracks are the result.

Soft spots and patches may also be caused during grinding through overpressure that has been enough to draw the temper of the article but has not generated enough heat to cause " ring cracking." Soft spots are also caused by decarbonised surface, the surface having had its carbon removed while in contact with an oxidising atmosphere in the furnace when heating for hardening—the ordinary smith's hearth has caused many soft spots through the use of too much blast. Contact of cold tongs, splashing during quenching and unequal heating are all causes for soft spots.

The fracture of a hardened piece of steel or a tool will give indications of its heat treatment, a coarse, crystalline " staring " fracture is usually a sign of overheating.

When a tool can be " touched " easily with a file after hardening, yet is hardest underneath, one can be certain that either sufficient skin has not been machined off or that the surface has been subsequently decarburised in heating for hardening. Sharp angles almost invariably cause trouble through cracks starting from them, cutting tools often fail to give the best results because of improper design. Angles and rakes improperly ground; or they are cracked when grinding, through too much pressure and insufficient supply of water.

The great source of trouble is, however, caused by overheating. Steel becomes overheated through many causes, heating too hot in order to save labour, heating too many articles at once when men are on piece work, attempting to get too much work on one heat in which case some of the articles may not get heated through and others get "burnt to death." Slow heating to a uniform correct temperature is of the utmost importance for all steels and is an absolute necessity in high speed steels until a bright red is reached when they may be urged without much damage but in all cases it is imperative that steel, no matter what its composition is, should never be heated in an oxidising atmosphere. It may be here remarked that however good a steel may be at the start, it is no better than the subsequent heat treatment it gets.

The heating of steel in every stage is work that should only be entrusted to skilled men. Many firms have installed pyrometers in their heat treating shops under the impression that they are infallible, and that hardening and tempering, heat-treating, annealing, carburising, etc., can then be operated by unskilled men, and also that once having installed pyrometers nothing can go wrong in their heat treating shops, and that the operative has only to read the dial or other indicator and he knows the true heat the steel has reached, but never was there such a delusion in cases where unskilled men are operating.

There are several causes which militate against the pyrometer indicator being a true record. First of all there is the location of the couple or couples in the furnace. The couples are placed there, but whether they register the heat of the furnace or the piece being heated is quite another matter. The couples may be in the heat of a cutting flame and be registering the heat of that and yet the piece being heated be nowhere near the heat that is registered and on being quenched is not correctly hardened, or in case of annealing, may not be correctly annealed, or, in case of being carburised, may not be up to the heat at which the gases emanating from the casing mixture will penetrate. The couples may be in a cool part of the furnace and registering correctly the heat that obtains there and yet the article may be in the path of a cutting flame and burnt rotten, but, according to the pyrometer they have not been overheated at all. Again pyrometers need frequent calibration and then readings in consequence are not correct and very often no correction of readings is ever made for the cold junction where thermo couples are used.

Experience is needed to do heat treating correctly. The man will know his furnace and how it is working. He will use his pyrometer as a check on his eye and his eye as a check on his pyrometer. He will or should know that there is a time factor as well as a heat factor in all heating, quenching, and tempering operations. He will know that steel does not become evenly heated through in a moment and

that neither the changes in hardening or tempering take place like a flash of lightning but that the time factor has importance.

I have laid particular stress on all this because all these principles from the steel to the finished product, although previously given as treatment for tool steels, apply equally to all classes of steel that have to be manipulated, from a penknife blade to a big gun, or a needle to huge marine shafting. Having got his correct heat for quenching, whether in air, oil or water, which heat is usually fixed by the maker and is arrived at by taking a thermal curve which will indicate the calesence and recalesence points and it is from these that are fixed the degrees of heat at which the steel should be heated.

Now, quenching in water whether it is a big forging, a large bar, or a tool, no matter how simple it may be, will always set up strains and this is where the skilled heat treater or hardener comes in. Although experience has furnished him with a few standard rules such as fillets being less dangerous than sharp corners, filling holes with clay, dipping thick portions first if possible so that the force of their contraction will be exerted on the thinner portions while they are still warm, and quenching hollow tools or forging in such a manner as will prevent the formation of a cushion of steam, vapour or oil smoke, which would preclude the quenching medium "striking"; "setting" tools or bars so that they will come back into the required position when quenched, "dancing" where articles are only partially hardened so that they will taper down in hardness from very hard to the soft and leave no sharp line of demarcation that would cause rupture. He will go beyond these rules and consider the properties and laws of cooling bodies and the effect of mass and will so manipulate them not only on these properties and laws but with the addition of the lines he has gained by long and watchful past experience and so turn out his product with a minimum of waster.

Concerning the steels that are used for what one may term constructional purposes, by which I mean the construction of machinery, the moving parts thereof, automobiles, wartime tools and the like, and not the heavy bulk steels used in buildings and the construction of the hulls of ships. In ordering these machinery and constructional steels, users are often very vague as to their requirements and use such terms as mild steel, hard steel, medium steel. What one user may class as medium steel may be another user's hard steel and what a third user may class as mild steel may mean anything from .10 carbon up to .40 carbon and in the absence of previous knowledge of the user's requirements or of the purpose for which the steel is to be used, it is often difficult for the steel maker to know exactly what is required. As an approximate guide straight carbon constructional steels may be roughly classed as case hardening steels.

Dead soft steel with a carbon range of	0.08	*to*	0.10
Welding steel	,, ,, ,,	0.10	,,	0.18
Mild steel	,, ,, ,,	0.20	,,	0.30
Medium steel	,, ,, ,,	0.30	,,	0.40
Half hard steel	,, ,, ,,	0.40	,,	0.60
Hard steel	,, ,, ,,	0.60	,,	1.00

These must however not be taken as a hard and fast line but as British practice on general lines and those of you who read American technical journals where similar terms of classification are used, will find the carbon content of the steels not quite agreeing with these and there are also slight differences for continental practice. In these and all other makes of steel, however, analysis is not everything, because it will not give the quality of the base materials constituting a furnace charge nor will it indicate the careful practice in making the steel nor the care used in its subsequent manipulation into bars, which are reason why some steels are apparently dearer than others on first costs.

We will now run over the various steels that are available for the various uses of the engineers. First of all, take the dead soft steels which as aforementioned range from 0.8 to 0.10 in carbon which are used where extreme softness and ductility are called for. These steels will respond to and be improved by subsequent heat treatment. Then there are the case hardening steels which are straight carbon, nickel steels and nickel chrome steels. Steels for case hardening require to be made specially for the purpose not only in the selection of the base from which they are made but in the working of the furnace in which these steels are made and even in the subsequent manipulation into bars.

The straight carbon steels have usually one of the two following analyses :

C	0.10	*to*	0.14	*or*	*C*	0.15	*to*	0.18
Si	0.08	,,	0.12	,,	*Si*	0.10	,,	0.15
Mn	0.70	,,	0.90	,,	*Mn*	0.70	,,	0.90

and after treatment according to the ordinary practice of casing at 900° to 930° C., cooling down in box, reheating 875 to 900° C. and quenching in cold water to refine the core and afterwards again reheating to 760° to 780° C. and quenching in cold water to harden the case. The cores of the case hardened piece will give in the lower carbon one a M.S. ranging from 27 to 35 tons a yield of 20 to 22 tons with an elongation of 40 to 49 per cent. and a reduction of area of 63 to 67 per cent. The higher carbon one will after the same treatment give a core of 40 to 42 tons M.S. a yield of 27 to 30 tons elongation of 28 to 30 per cent. and a reduction of area of 60 to 63 per cent. Many users object to giving case hardened articles the treatments here set out on the ground of reducing cost or too much

trouble, but if they want the best results, they will not only carry out the full programme but take care that the heats are really within the ranges specified.

Other case hardening steels are the three per cent. nickel and the five per cent. nickel, which have carbons in the regions of .15 to .20 and Mn. of .40 to .50 which are used where greater toughness and higher tensile tests on the core are needed and also greater surface hardness. A further case hardening steel is the nickel chrome one which has an analyses of approx. C. 13 to .18 Mn. of .50 to .60 nickel content ranging from three to 3½ per cent. and a chromium content of .60 to .75 which is mainly used for gears, camshafts, chain wheels and similar articles where great toughness and resistance to wear are indicated.

Of late years the practice of nitriding has come into use and a special steel of high aluminium content has been devised by which it is claimed that harder surfaces can be obtained, but it is quite within the bounds of possibility that the ordinary case hardening steels can be and are adaptable to the nitriding process and that nickel and nickel chrome case hardening steels will lend themselves to nitriding with better results than the straight carbon steels, because it is now claimed that the addition of nickel and chrome to these high aluminium steels has the advantage of straightening and toughening the case, of strengthening and hardening the core by which better support is given to the case and the development of dispersion hardening in steels containing high aluminium and gives increased strength and elastic properties.

Other steels useful to the engineer are the *straight carbon* 30 *ton steel and the straight carbon* 40 *ton steel*, which are usually used in the normalised condition.

The 30 ton steel having a content of C, 28 to 40 Mn. .45 to .80.
,, 40 ,, ,, ,, ,, ,, ,, C. 45 ,, 55 Mn. .50 ,, .70
and will give tests of

M.S.	30 to 40 tons per cent.		40 to 50 tons per cent.
Yield ratio ...	50	and	50
Elongation ...	25	,,	20 respectively
Reduction ...	45	,,	40

the normalising heat in each case being 850° C.

One of the most useful steels is the three per cent. nickel steel with an analyses in the region of C. .30 to .55 Mn. .50 to .70 and Ni. 2.75 to 3.25 which hardens in oil from 850° C. and after tempering at various degrees of temperature will give pull tests of very useful ranges, a typical test being one which *after heating to* 850° *C. quenching in oil and afterwards tempering to* 560° *C. and cooling in air, will give a tonnage of :*

M.S.	57 *to*	60	*tons sq. in.*
Y	50 ,,	55	,, ,,
E	20 ,,	23	*per cent.*
R	55 ,,	60	,, ,,
Izod	40 ,,	50	*ft. lbs.*

Another useful No. steel with a wide range of tests is the five per cent. Ni. steel having an analyses in the region of

C. 30 *to* 35 *Mn.* .40/.70 *Ni.* 4.75 *to* 5.25

which when quenched in oil from 830° (820° *to* 840°) *has a range of from* 45 *to* 100 *tons max. stress the tempering rising from* 50° *C. at a time will give*

M.S. ranges from	65 *to*	105 *tons*	
Y ,, ,,	45 ,,	100 ,,	
E ,, ,,	$22\frac{1}{2}$ per cent.	down to	14 per cent.
R ,, ,,	61 ,,	,, ,,	47 ,, ,,

In the nickel chrome steels there are

nickel chrome steel

C. .33 to .35 Mn. 45 to 55 Cr. .93 to 1.05 Ni. 1.20 to 1.30 suitable for gears, which when quenched in oil from 820° to 830° C. will give a M.S. of 110 to 114 tons and a Brinnell of 447 and is ammenable to tempering and will give varying M.S. lower than 110 tons and of course of consequent reduction in Brinnell hardness.

Another one with C. .28 to .35 Mn. .60 to .70 Cr. .95 to 1.05 Ni. 1.90 to 1.20 which when quenched from 820° to 830° C. in oil has a very wide range after tempering to varying degrees of temperature.

There are others all of which after oil quenching and tempering at different temperatures will give degrees of hardness and pull tests to suit many diverse requirements.

There are also air hardening nickel chrome steels, which, although they may be oil quenched, are most suitable for air hardening in order to avoid distortion, a typical one having a C. .30 to 35 per cent. Mn. .40 to .60 Cr. 1.25 to 1.30 Ni. 4.25 to 4.75 will when hardened in air from 800° to 820° C. give a M.S. of 110 tons, Y of 95 tons, E of 15 per cent., R of 30 per cent., and an Izod of 15 to 20 ft. lbs. with a Brinnell hardness of 477 and, if quenched in oil, from 800° C. will give a M.S. of 115 tons and Y 100 tons with a slight reduction of E and R but a Brinnell of 500, the Izod in each case having about 15 to 20 ft. lbs. Chrome vanadium steels are also very useful steels a typical one having a C. content of .37 to .43 Mn. .60 to .95 Cr. 1.20 to 1.40 and Y .16 to .20. This steel does not harden when cooled in air and can be forged when at lower heat than Ni. Cr. steels and can be machined after heat treatment. Hardening heat 850°, quench in oil and afterwards temper at varying heats. Quenched in oil at 850° C. and tempered to 650° C. afterwards cooling in air, this steel will give M.S. 55 to 65 tons a yield ratio of about 75 per cent. and E. of 18 per cent. R. of 50 approximate.

A further very useful steel is nickel chrome molybdenum steel which when hardened and tempered to give a test of 80 tons M.S. is machinable and even when giving a M.S. of 95 to 100 tons may also be machined, but of course, at lower speeds. The quenching heat of this steel is 840° in oil and by tempering at heats ranging from 200° C. to 650° C. it will give maximum stresses ranging from 60 to 132 tons with elongations from 10 per cent. to 24 per cent. Reduction of area from 32 per cent. to 57 per cent. and Izods from 12 to 61 foot lbs. One of the useful properties of this steel is that it is not subject to temper brittleness.

Some users have either not facilities or don't want to be bothered with the heat treatment of nickel, nickel chrome, chrome vanadium or chrome molybdenum steels, and want to use them without heat treatment, but they will be well advised to buy them in the heat treated condition. Should, however, the heat treated condition be such as to make them unmachinable, they had far better send them back to the steel maker to be heat treated than have unsatisfactory results in their finished article ; in many of these the lightest of light finishing cuts will clear them up after the treatment.

My talk makes no pretence to exhaust the subject but is an attempt to help those who have to use and manipulate steel to avoid some of the pitfalls and ensure the best results in their practice.

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